

Quality Control of Minerals Management Service - Oil Company ADCP Data at NDBC: A Successful Partnership Implementation

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Abstract - The Minerals Management Service (MMS) requires that deep water oil drilling and production platforms in the northern Gulf of Mexico collect and provide current profile data to the National Data Buoy Center (NDBC). NDBC processes and displays the resulting currents on the NDBC website. NDBC has recently implemented quality control algorithms agreed upon by industry and the government. The resulting imagery and data, including quality control flags, are available on the publicly available NDBC website. The quality control algorithms and flags are presented and comparisons of the resulting files are described.

Oil companies must collect current profile data when drilling wells or operating production platforms in water greater than 400 meters deep. They are required to collect the data at 20 minute intervals and transmit the data via FTP to NDBC. The data are received, decoded, and quality controlled at NDBC. The current profiles are then formatted in Temperature Salinity and Current (TESAC) messages and transmitted over the Global Telecommunications System (GTS). The data are also viewed over the NDBC website as columnar listings and current vector stick plots.

In order to determine the quality control algorithms for the current profiles, a committee of oil company, industry, and government representatives determined an approach that includes both individual bin (depth level) and profile algorithms. The algorithms take advantage of the fact that the Teledyne RDI Acoustic Doppler Current Profiler (ADCP) collects error velocity, percent good statistics for 3 and 4 beams, and correlation matrices and echo amplitudes for each beam. The algorithms described in this presentation were then implemented and flags generated for each quality control test. A total of nine flags are assigned within the NDBC database. The flags indicate good data (3), suspect data (2), or bad (1) data. Only bad data are not reproduced or plotted on the NDBC real-time webpage. Results from the implementation are being reviewed, but a quick look indicates that the algorithms are returning accurate descriptions of the ADCP data. The stick plots of ocean

current with depth are much “cleaner” following the quality control implementation.

The implementation of the quality control algorithms was delayed by Hurricanes Katrina and Rita, which impacted both the NDBC and the oil industry in the Gulf of Mexico. NDBC is now resubmitting past data files through the quality control algorithms to insure that all data at NDCB have been quality controlled. The results of this effort (including the quality control algorithms) are being shared with Integrated Ocean Observing System (IOOS) partners in an effort to standardize quality control of oceanographic data.

I. INTRODUCTION

The Minerals Management Service (MMS) requires that deep water oil drilling and production platforms in the northern Gulf of Mexico collect and provide current profile data to the National Data Buoy Center (NDBC). Oil companies collect current profile data using Teledyne RD Instruments, Inc. (TRDI) Acoustic Doppler Current Profilers (ADCPs), when drilling wells or operating production platforms in water greater than 400 meters deep. They are required to collect the data at 20 minute intervals and transmit the data via FTP to NDBC. NDBC processes, quality controls, and displays the resulting currents on the NDBC website. A committee of oil company, industry, and government representatives determined an approach that includes both individual bin (depth level) and profile algorithms. NDBC has recently implemented quality control algorithms agreed upon by industry and the government. The resulting imagery and data, including quality control flags, are available on the publicly available NDBC website. The quality control algorithms and flags are presented and comparisons of the resulting files are described.

II. QUALITY CONTROL ALGORITHMS

The quality control algorithms discussed are specific to external power operated 38 and 75 kHz TRDI ADCPs. Seven tests are performed on each bin and those most severe of the flags will be assigned to the bin. An overall profile status is assigned, based on bin results.

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The sequence of tests follows:

1. Built-In Test (BIT)
2. Error Velocity Test
3. Percent Good Test
4. Correlation Magnitude Test
5. Vertical Velocity Test
6. Horizontal Velocity Test
7. Echo Intensity Test

The tests will result in Failed Data (flag=1), Suspect Data (flag=2), or Good Data (flag=3). These flags are included in the NDBC data base for each bin.

The built-in test is not available on all TRDI ADCPs, but when it is, the bin is flagged as GOOD if the BIT result is zero and SUSPECT if the BIT result is non-zero. No failed result is possible, because the BIT warns of possible health issues.

The following tests are run for individual bins for each ADCP.

The error velocity is a measure of the variance of the horizontal velocity. It is measured from the difference between the vertical velocities measured between the two orthogonal components of the horizontal velocity. Low error velocities indicate that the horizontal flow measured by the ADCP is homogeneous. The following thresholds have been determined for the error velocity test. If the error velocity for a bin is less than 15 cm/s, the data are flagged as GOOD. Error velocities exceeding 15 cm/s and less than or equal to 30 cm/s are SUSPECT data. The bin is FAILED if error velocities exceed 30 cm/s.

The percent good test is a measure of the fraction of pings that pass various error thresholds for each bin. Because the strength of the pings differs for the 38 kHz and 75 kHz ADCPs, the percent good numbers vary also. For the 75 kHz ADCP system, data are flagged as GOOD if the percent good for a bin exceeds 10 percent. Percent good is flagged as FAILED if the percent good is below 5 percent and SUSPECT if the values fall between 5 and 10 percent. Percent good values exceeding 25 percent for the 38 kHz ADCP are flagged as GOOD. FAILED values fall below 22 percent and SUSPECT values are between 22 and 25 percent. Percent good values are calculated for 4- and 3-beam solutions.

The correlation magnitude is a measure of the precision of the horizontal velocity measurement. It relies on a measure of how much the particle distribution in the water column changes within a beam between pings. A correlation magnitude is calculated internally for each beam. Because the measurement is based on the strength of the signal, the test is different for the 38 kHz narrow band, 38 kHz wide band, and 75 kHz ADCPs. The wide band 38 kHz

ADCP correlation magnitudes are flagged as GOOD if three of the four correlation magnitudes reported for a bin are greater than 190. If one or none of the correlation magnitudes is greater than 190, the bin IS FAILED for the correlation magnitude test. Data are SUSPECT if the correlation magnitude is good for two of the beams. If correlation magnitudes for at least three of the four beams exceed 110, the correlation magnitudes for the narrow band 38 kHz ADCP are flagged as GOOD. If two beams exceed 110, the data are SUSPECT and if one or no beam correlation magnitudes exceed 110, the data are FAILED. The 75 kHz ADCP correlation magnitude is flagged as GOOD if three or four of the beams have correlation magnitudes greater than 64. If two of the four beam correlation magnitudes exceed 64, the data are flagged as SUSPECT. The bin is flagged as FAILED if one or none of the correlation magnitudes exceed 64.

Following the correlation magnitude tests, the next test is the vertical velocity test. Areas of high vertical velocity indicate instability in the flow and may suggest that the horizontal velocities are not homogeneous within the four beams being sampled. Homogeneity is an assumption for GOOD horizontal currents. If vertical velocities measured by the ADCP are less than or equal to 30 cm/s, the data are flagged as GOOD. If the vertical velocities are equal to or greater than 50 cm/s, the data for the bin are flagged as FAILED. Vertical velocities between 30 and 50 cm/s are tagged as SUSPECT.

The horizontal velocity test checks for velocities that exceed those expected in an area. The thresholds established for these tests were derived specifically for the northern Gulf of Mexico, where the high-speed Loop Current and associated eddies are known to impact oil operations. The ADCPs report north-south and east-west components of the velocity and each are tested separately. If horizontal velocities are less than or equal to 125 cm/s, the bin is flagged as GOOD. A bin is flagged as FAILED, if the horizontal velocities exceed 200 cm/s. The horizontal velocity in the bin is SUSPECT, if it falls between these two extremes.

Echo intensity is a measure of the signal strength returned to the transducer from scatterers in the water column. High echo intensity may indicate obstructions (risers, etc) or schools of fish in the path of the beam. Low echo intensity indicates that not enough scatterers are present in the beam path to return the energy to the transducer or indicate the limits of the transducer range. Echo intensity in a bin is compared to echo intensity in adjacent bins to determine whether the bin is to be flagged.

If there is no increase greater than 30 counts from the previous bin for a given beam, the bin is flagged as GOOD for echo intensity. The data are SUSPECT if the rise on one beam is greater than 30 counts. The bin is flagged as

FAILED for echo intensity, if the rise in two or more beams for a bin is greater than 30 counts.

Once the individual bin tests are complete, a final check is made to determine the quality of the entire profile. The profile is flagged GOOD if all of the bins have been flagged as good. If less than half of the bins are flagged as suspect or bad, the profile is flagged as SUSPECT. The entire profile is flagged as FAILED, if more than 50 percent of the bins are flagged as suspect or failed.

The quality control flags are stored along with the data and supporting information by bin. An example is provided in Table 1. The quality flags represent:

- Position 1 = overall bin quality
- Position 2 = bit test result
- Position 3 = error velocity result
- Position 4 = percent good (3 or 4) result
- Position 5 = correlation magnitude result
- Position 6 = vertical velocity result
- Position 7 = north-south speed component result
- Position 8 = east-west speed component result
- Position 9 = echo intensity test for bins > 15

III. PROGRESS

NDBC implemented the quality control algorithms into the real time processing stream in March 2006. Since that time oil company data from between 40 and 50 rigs and platforms have been processed and stored each day. Many of the oil companies collect the data at 10 or 20 minute intervals and FTP the data to NDBC soon after the data are collected.

The data collected prior to March 2006 are currently being reprocessed using the quality control algorithms and stored in the Historical Database at NDBC. Additionally, delayed-mode ADCP data collected from bottom mounts (with no real-time transmission capability) are being collected by NDBC as the ADCPs are retrieved and the data sent to NDBC and those data are being processed through the quality control algorithms, also.

IV. RESULTS

The results of the data quality control processing for a single ADCP are presented in Table 1. The data were collected at 1850 GMT 27 February 2006. The instrument number is 1 and the bins presented are represented. A break is shown between 13 and 19 in order to show the test results below bin 15 and to show what occurs near the end of the ADCP range. The bin depths indicate that 32 meter bins are used in this deployment. The current direction and speed are presented in the next two columns. The error velocity and vertical velocities are presented in the two following columns. The percent good columns indicate what

percentage of the three and four beam solutions are provided by the ADCP. If all four beam solutions are good, then that is presented. The echo intensities for each beam used in the final quality control test and the correlation magnitudes for each beam are provided in the final data columns.

The quality control algorithm results follow. No BIT was reported for this ADCP deployment. Through bin 13 all tests indicate GOOD data. The final number is zero, because the echo intensity test is not completed for bins 1 through 15. In bins 19 through 32, the echo intensity test is completed and the results are GOOD. In bin 33, the error velocity test returns a SUSPECT result because the error velocity is missing. The percent good test for this bin fails because the percent good is 19%, below the threshold of 22% for the 38 kHz ADCP at this site. The correlation magnitude test returns a SUSPECT result because 2 or the four beams return values in excess of the threshold values. Vertical values return a GOOD data quality flag in the next position. The two following flags represent the north-south and east-west components of the current and both indicate GOOD data quality. The final flag indicates GOOD echo intensities at this bin. The first flag is assigned a value of 1 to indicate that the bin is FAILED because that is the lowest value assigned during the data quality tests. The last two bins in the profile are missing current speed and direction as well as error and vertical velocity values and therefore the bin fails data quality and is flagged as FAILED.

Figures 1 and 2 show the before and after data quality test results in graphic form. High speed currents in the bottom layers cause the 0 to 100 cm/s range to be selected for the graphics and the true speeds and directions are difficult to extract from the plot. The errant data are removed from the quality controlled plot. The scale of the plot reverts to a 0 to 50 cm/s range and the speeds and directions are more easily observed. The areas of FAILED data are left unoccupied.

In a review of 32 stations to determine the impact of the quality control algorithms, a number of impacts were observed. A quarter of the stations (8) that were quality controlled resulted in no changes to the data. Another five stations had minor changes to the data (2-5 points over 2 days). In another quarter of the stations (8) one or more of the bins farthest away from the sensor were omitted following the quality control algorithms. In nine of the stations a large number of points scattered over many bins were flagged by the quality control software. One station exhibited a finite number of bin errors over a limited time, which may indicate some type of event that impacted the beams. At one station, the impact was not discernable.

IV. CONCLUSIONS

NDBC has implemented quality control algorithms for oil company ADCP data collected under an MMS program. The quality control algorithms are successfully removing

data that do not meet agreed upon quality control thresholds.
Data that pass the quality control algorithms are displayed in

tabular and graphic form and stored in short term storage on the NDBC website.

Year	m	d	hh	mm	l	Bin	Dep	Dir	Spd	ErrV	VerV	3	4	EI1	EI2	EI3	EI4	C1	C2	C3	C4	Flags
2006	2	27	18	50	1	1	69	234	19.7	0.9	-2.6	0	100	191	197	190	194	227	232	231	233	393333330
2006	2	27	18	50	1	2	101	202	15.3	0.7	-1.6	0	100	165	173	169	168	240	241	242	237	393333330
2006	2	27	18	50	1	3	133	210	11.7	2.4	-1.5	0	100	164	169	166	165	242	242	241	243	393333330
2006	2	27	18	50	1	4	165	218	12.1	-0.8	-1.5	0	100	160	166	163	163	242	240	240	242	393333330
2006	2	27	18	50	1	5	197	210	16.2	-2.2	-1.1	0	100	160	164	163	156	240	243	243	237	393333330
2006	2	27	18	50	1	6	229	207	20.5	-1	-0.5	0	100	157	149	147	156	235	235	234	245	393333330
2006	2	27	18	50	1	7	261	214	22.3	0.4	-0.8	0	100	135	129	125	140	240	240	238	235	393333330
2006	2	27	18	50	1	8	293	222	16.4	0.7	-0.4	0	100	118	123	120	122	240	238	240	241	393333330
2006	2	27	18	50	1	9	325	217	13	1.2	0	0	100	115	130	127	119	242	239	240	242	393333330
2006	2	27	18	50	1	10	357	238	12.5	0	-0.8	0	100	120	142	138	122	236	239	239	236	393333330
2006	2	27	18	50	1	11	389	254	11.5	-0.8	0.1	0	100	124	151	151	126	242	240	241	241	393333330
2006	2	27	18	50	1	12	421	241	12.3	0.1	-0.2	0	100	137	154	152	140	240	240	243	240	393333330
2006	2	27	18	50	1	13	453	246	11.1	0	0	0	100	141	140	139	145	241	243	241	241	393333330
2006	2	27	18	50	1	19	645	216	9.2	3.1	-0.8	0	100	105	107	105	110	241	239	241	241	393333333
2006	2	27	18	50	1	20	677	275	7.6	0	0	0	100	99	102	102	104	240	240	240	240	393333333
2006	2	27	18	50	1	21	709	279	9.1	-0.8	0.1	0	100	95	102	101	100	241	239	240	239	393333333
2006	2	27	18	50	1	22	741	270	10.3	1.6	0.1	0	100	90	98	96	99	240	241	241	241	393333333
2006	2	27	18	50	1	23	773	272	12	0.2	0.3	0	100	91	91	90	96	239	240	240	240	393333333
2006	2	27	18	50	1	24	805	279	10	-0.3	0.2	0	100	87	84	83	95	239	239	239	239	393333333
2006	2	27	18	50	1	25	837	284	7.7	0.9	0.4	0	100	82	72	70	92	236	240	238	239	393333333
2006	2	27	18	50	1	26	869	301	7.1	1.4	0.5	0	100	77	67	61	86	232	238	231	237	393333333
2006	2	27	18	50	1	27	901	308	9.5	0.9	0.5	0	100	70	63	60	80	228	236	227	235	393333333
2006	2	27	18	50	1	28	933	313	8	-1.1	0.8	0	100	64	58	57	71	225	235	228	225	393333333
2006	2	27	18	50	1	29	965	293	6	-1.6	0.9	0	100	59	62	70	66	225	232	221	224	393333333
2006	2	27	18	50	1	30	997	300	7	-0.5	-0.3	1	99	54	82	79	58	229	230	231	218	393333333
2006	2	27	18	50	1	31	1029	230	4.5	-1.9	0.1	1	99	50	84	68	53	222	223	235	219	393333333
2006	2	27	18	50	1	32	1061	231	4.6	-2.1	-1.6	1	99	51	58	50	52	211	239	225	212	393333333
2006	2	27	18	50	1	33	1093	171	4.9	MM	-0.1	19	0	52	50	46	50	0	243	202	39	192123333
2006	2	27	18	50	1	34	1125	MM	MM	MM	MM	0	0	49	40	47	47	0	223	198	0	192121113
2006	2	27	18	50	1	35	1157	MM	MM	MM	MM	0	0	47	42	48	48	0	208	200	0	192121113

Table 1. Example of an NDBC historical file for quality controlled ADCP data. The indicators across the top represent year, month, day, hour, minute, instrument number, bin number, bin depth in meters, direction and speed of the current, error velocity, vertical velocity, percent good 3 beams, percent good 4 beams, echo intensity for the first, second, third, and fourth beams, correlation magnitudes for the first, second, third, and fourth beams, and the quality control flags.

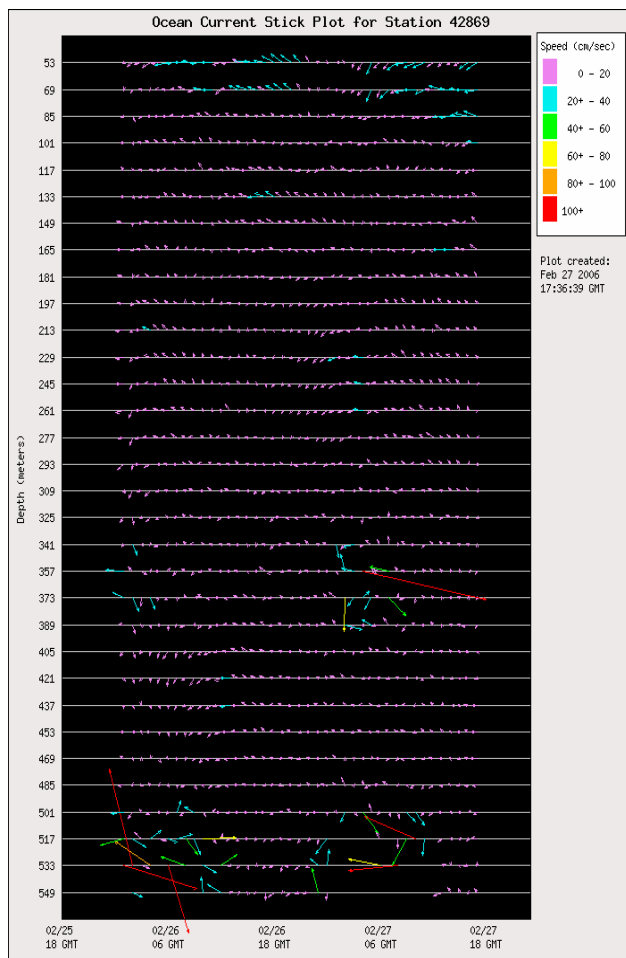


Figure 1. Non-quality controlled current time series plot for Station 42869.

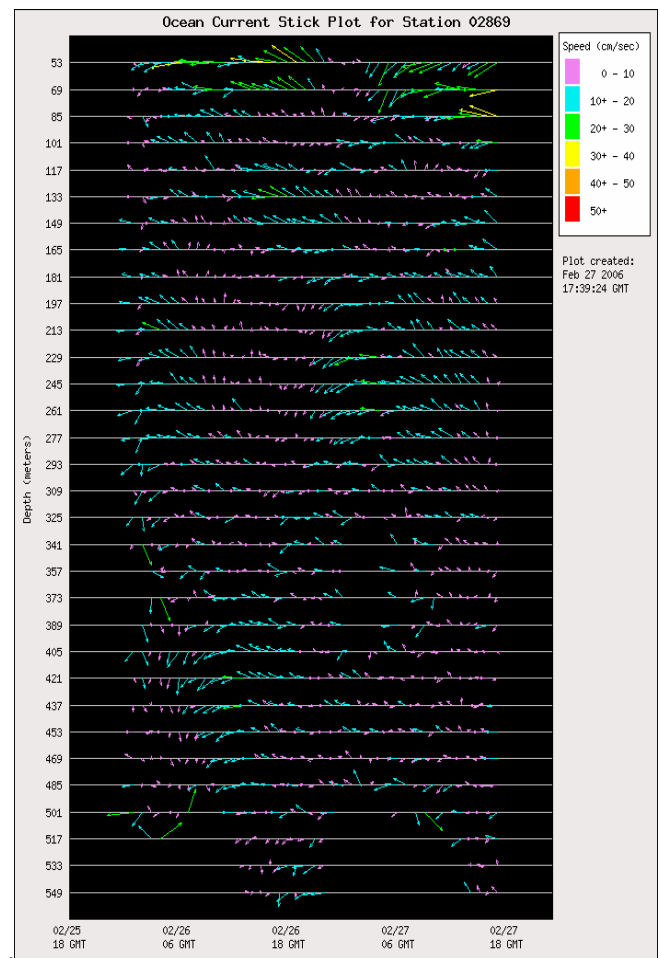


Figure 2. Quality controlled current time series plot for Station 42869